APPARATUS AND METHODS FOR APPLYING A STRAP AROUND A BUNDLE OF OBJECTS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application No. 60/442,345 filed January 24, 2003; where this provisional application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to apparatus and methods for applying flexible straps around a bundle of objects using a strap coated with a water soluable surface adhesive; this type of strap is used in applications such as strapping cellulose pulp bales where it is advantageous for the strap to readily dissolve along with the bale in repulping operations.

Description of the Related Art

Strapping machines for applying flexible straps around bundles of objects have been developed in recent years and are disclosed in Patents: US Patent No. 5,560,180, US Patent No. 6,363,689, and US Patent Application Publication No. US 2002/0116900 A1. A conveyor belt typically conveys a bundle to a strapping station where straps are automatically applied before the conveyor belt moves the strapped bundle away from the strapping station.

Figure 1 is a front isometric view of a strapping machine 10 in accordance with the prior art. The strapping machine 10 has several major assemblies, including a feed and tension assembly 15, an accumulation assembly 14, a sealing assembly 40, a track assembly 50, a control system 60 having an operator interface region 65. The strapping machine 10 may also include a frame 70 that structurally supports and/or encloses the

major subassemblies of the machine. The assembly and purpose of the major assemblies are described in detail in U.S. Patent No. 6,363,689.

Typical strapping machines employ a tensioning apparatus that provides tensioning of the strap about the bundle. A sealing head then seals the strap, typically through the use of heated mechanism in concert with water to accelerate the adhesive and to complete the bundling operation. The addition of water to the sealing process requires that the waste water must be discharged and properly discarded. This sealing process creates a risk of applying either too much or not enough water such that the strap bond does not achieve its full strength and creates a need to develop a containment and disposal system for the water used in the sealing process.

Although desirable results are achievable with existing strapping machines, some operational drawbacks exist. Present machines typically utilize a system of electro-hydraulic and electro-pneumatic controls to accomplish the various machine functions. In recent years, modern industrial machines have moved away from the use of hydraulics due to environmental and safety concerns. In addition, the use of pneumatics can, in certain applications, lead to reliability issues due to contaminants in the air supply system, which can affect the timing and sequencing of the various machine operations.

SUMMARY OF THE INVENTION

The description presented below describes a strapping machine and method of applying a strap around a bundle of objects. The embodiments described herein are comprised of major assemblies that may be configured to be modular, thus these assemblies may be easily altered to fit various production and package specifications. A control system can augment the mechanical components of the strapping machine through automated operating and control signals. For example, during a primary tensioning operation, the control system monitors position signals from a feed pinch roller position sensor and terminates primary tensioning when a slippage condition is determined. The control system then initiates a secondary tensioning operation. The secondary tensioning

operation lasts for a predetermined amount of time while the control system initiates a strap sealing operation that secures the strap around the bundle.

In one aspect of the invention, a strapping machine for bundling objects comprises a dispenser for feeding a strap from at least one strap coil; an accumulator for receiving the strap from the dispenser and storing excess strap during a tensioning operation; a track assembly extending substantially about a strapping station, the track assembly capable of receiving the strap and then releasing the strap from a plurality of biased covers during a tensioning operation, the covers being biased in a closed position while the strap is guided through a track channel; a feed and tension unit for receiving the strap from the accumulator, for feeding the strap substantially through the strap channel of the track assembly, and for retracting excess strap during the tensioning operation, the feed and tension unit including a plurality of drive and pinch wheels for guiding the strap through a "V-shaped" path; a sealing head assembly located in proximity to the strapping station having a plurality of cams and cam followers mounted on a shaft, the cams being mechanically sequenced for repeatedly and accurately gripping, cutting, and dry sealing the strap around a bundle of objects, the gripping and cutting being accomplished by a cutter-gripper assembly that includes at least one gripper for gripping a free end of the strap and a cutting device for cutting the strap to create two overlapping strap ends; and a main drive assembly having at least one motor for providing power to the feed and tension unit and the sealing head assembly.

In another aspect of the invention, a method for applying an adhesive-coated strap around a bundle of objects comprises the steps of guiding the strap around the bundle of objects; securing the strap about the bundle of objects; gripping at least one end of the strap to maintain tension in the strap during a bundling operation; cutting the strap to produce two overlapping strap ends; inserting a heater blade between the overlapping strap ends; dry sealing the overlapping strap ends through a mechanically timed dwell means while pressing the strap ends against the heater blade, the heater blade being in contact with the bonding surfaces of the strap; removing the heater blade; pressing the adhesive-coated

portions of the strap ends together; applying pressure to the sealed strap to cure and cool the adhesive; and releasing the strap to produce a strapped bundle of objects.

In yet another aspect of the invention, a strapping machine for bundling objects, comprises a first means for dispensing a strap from at least one strap coil; a second means for receiving the strap from the first means during a strap feeding operation and for accumulating excess strap during a tensioning operation; a third means for releasably retaining the strap around a bundle of objects and subsequently releasing the strap through a plurality of biased covers during the tensioning operation; a fourth means for receiving the strap from the second means and applying a sufficient force to the strap to direct the strap around the bundle of objects as defined by the third means, the fourth means further configured to retract excess strap during the tensioning operation; a fifth means for mechanically controlling the gripping, cutting, and dry sealing of the strap once the strap is sufficiently located about the bundle of objects, the fifth means defining where the strap enters and exits the third means; and a sixth means for providing power to at least some of the major components of the machine.

These and other benefits of the present invention will become apparent to those skilled in the art based on the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric and partial fragmentary view of a strapping machine under the prior art.

Figure 2 is an isometric view of one embodiment of an entire strapping machine.

Figure 3 is a picture of one embodiment of a strap dispenser having one strap coil.

Figure 4 is picture of a strap exhaust switch and entry roller attached to the strap dispenser of Figure 3.

Figure 5 is an isometric view of another embodiment of a strap dispenser having one active and one reserve strap coil.

Figure 6 is a partial isometric view an accumulator attached adjacently to a track assembly in accordance with one embodiment of the invention.

Figure 7 is an exploded isometric view of an accumulator drive motor in accordance with the accumulator of Figure 6.

Figure 8 is an exploded isometric view of a strap diverter arrangement for controlling the path of the strap in the accumulator of Figure 6.

Figure 9 is a first isometric view of a feed and tension unit in accordance with one embodiment of the invention.

Figure 10 is a partial front elevational view of the strap path through a portion of the feed and tension unit of Figure 9.

Figure 11 is an enlarged partially-exploded isometric view of a pair of inner and outer strap guides of the feed and tension unit of Figure 9.

Figure 12 is a cross-sectional view taken along line 12-12 from Figure 9 of the "L-shaped" inner and outer guides of Figure 11 that form a guide slot for the strap.

Figure 13 is an isometric view of a sealing head assembly in accordance with one embodiment of the invention.

Figure 14 is a top elevational view of the sealing head assembly of Figure 13.

Figure 15 is a back elevational view of the sealing head assembly of Figure 13.

Figure 16 is an isometric view of a press platen and a cutter prior to installation in the sealing head assembly of Figure 13.

Figure 17 is an enlarged isometric view of the press platen and cutter of Figure 16 after assembly.

Figure 18 is a picture of the main drive assembly in accordance with an embodiment of the invention.

Figure 19 is another embodiment of the motor and belt configurations of the main drive assembly where none of the belts make a 90-degree turn.

Figure 20 is an isometric view of a track assembly in accordance with an embodiment of the invention.

Figure 21 is a partial sectional view of a straight section of the track assembly of Figure 20 taken along line 21-21.

Figure 22 is an isometric view of a corner section of the track of Figure 20.

Figure 23 is a partially exploded isometric view of a straight section of the track assembly of Figure 20.

Figure 24 is a picture of a track opening solenoid.

Figure 25 is a front elevational view of a control system.

Figure 26 is an isometric view of the interaction of the main drive assembly, the feed and tension assembly and the sealing assembly.

In the drawings, identical reference numbers identify identical or substantially similar elements or steps.

DETAILED DESCRIPTION OF THE INVENTION

The present disclosure is directed toward apparatus and methods for strapping bundles of objects. Specific details of certain embodiments of the invention are set forth in the following description, and in Figures 2-27, to provide a thorough understanding of such embodiments. A person of ordinary skill in the art, however, will understand that the present invention may have additional embodiments, and that the invention may be practiced without several of the details described in the following description.

Throughout the following discussion and in the accompanying figures, the strap material is shown and referred to as a particular type of material, namely, a flat, two-sided, tape-shaped strip of material. This definition is adopted herein solely for the purpose of simplifying the description of the inventive methods and apparatus. It should be understood, however, that several of the methods and apparatus disclosed herein may be equally applicable to various types of strap material, and not just to the flat, two-sided, tape-shaped material shown in the figures. Thus, as used herein, the terms "strap" and

"strap material" should be understood to include all types of materials used to bundle objects, for example, synthetic, metallic, or some other more rigid strap material. One type of strap that may be used with the embodiments described below is a paper web strap that can be successively plow folded and glued into a continuous paper strap. Another type of strap that may be used is a cord-type strap.

Figure 2 illustrates a strapping machine 100 in accordance with an embodiment of the invention shown with a typical conveyor 110 for moving bundles in and out of a strapping station 120, which is surrounded by a track assembly 700. The strap 102 employed during bundling operations is fed about the track assembly 700 in a strap-feed direction 132 that is generally counter-clockwise. A frame 140, which can be affixed to the floor in either a temporary manner or a more permanent manner, supports the strapping machine 100. The independently powered conveyors 110 are independently supported on conveyor frames 145. The conveyor frames 145 do not support the strapping machine. Some of the other major assemblies of the strapping machine 100 include a control system 800 for programming and controlling various functions of the machine, an accumulator 300 for housing the strap 102 (not shown), and a feed and tension unit 400 for receiving and feeding the strap 102 around a bundle. The feed and tension unit 400 is fed strap from a strap dispenser assembly 200. The strapping machine 100 is further configured with a sealing head assembly 500 (not shown) for sealing the strap around the bundle and a main drive assembly 600 (located underneath the conveyor in the present view) for powering various aspects of the machine during operation. At least some of the major assemblies can be of modular construction, which allows them to be used in multiple frame configurations or attached as add-on components to existing strapping machines.

<u>Strap Dispenser</u>

Figures 3 and 4 illustrate one embodiment of a modular strap dispenser 200 that can be used with the strapping machine 100. The dispenser 200 includes a mounting shaft 202 extending outwardly from the frame 204 between an inner hub 206 and an outer hub 208. A spring brake 210, hidden behind the 206 hub in Figures 3 and 5, is operatively

coupled to the mounting shaft 202 and to the frame 204. When in a release mode, the brake 210 allows the rotation of the mounting shaft 202; whereas otherwise the brake 210 acts to restrict the rotation of the mounting shaft 202. A mounting nut 212 is rotatably mounted on the mounting shaft 202 and supports the inner hub 206 and the outer hub 208.

In addition and also referring to Figure 4, the dispenser 200 can include a guide pulley 216 held in place by a retainer 218. The guide pulley 216 permits the strap 102 to be smoothly routed from a strap coil 214 into the feed and tension assembly 300 (not shown). The presence of the strap 102 as it is routed over the guide pulley 216 triggers a strap exhaust switch 222 as it enters an accumulator assembly guide 318.

Figure 5 illustrates another embodiment of a strap dispenser 200. In the illustrated embodiment, the dispenser 200 has more than one strap coil, thus allowing one coil 214 to act as a reserve coil while a second, active coil 214 supplies the strapping machine 100. The active coil 214 in the illustrated embodiment is the bottom coil, however one skilled in the art will recognize that the active coil could be either the upper or bottom coil.

Accumulator:

Figures 6 through 8 illustrate one embodiment of an accumulator assembly that can be used with the strapping machine 100. Figure 6 is an exploded isometric view of an accumulator 300. Figures 7 and 8, in particular, illustrate the accumulator drive arrangement and the automatic feed mechanism of the accumulator 300 of Figure 6. The accumulator 300 includes first and second sidewalls, 302 and 304, respectively, that substantially enclose a chamber 306, which is capable of storing at least some quantity of strap 102 for rapid feeding, as well as for temporarily storing the strap 102 that is retracted back during the tensioning process. The chamber 306 is substantially enclosed by the first sidewall 302 and the second sidewall 304.

Figure 7 illustrates the primary components of the accumulator 300 that are utilized during a strap feeding operation. An accumulator motor 310 powers an accumulator drive wheel 312 to feed the strap 102 between the accumulator drive wheel

312 and an accumulator pinch wheel 314. An accumulator feed switch 316 can be located proximate the accumulator drive and pinch wheels, 312 and 314, respectively, to detect the presence of the strap 102 and to transmit a control signal to the accumulator motor 310.

Figure 8 illustrates the primary components utilized during an automatic feeding operation. When the strap 102 is fed into the strapping machine 100 by the accumulator motor 310, a diverter solenoid 320 pulls a strap diverter 322 into the lower entrance of the chamber 306, wherein the strap 102 is then directly routed to the feed and tension unit 400 and then eventually around the track assembly 700. The automatic feeding operation is used to fill the strapping machine 100 with strap 102. There is no manual counterpart.

The strap diverter 322 has a series of strap guide rollers 324, which also extend into the lower section of the accumulator chamber 306. The strap diverter 322 is used only during the automatic feed mode, which precedes the normal automatic mode when the machine is running in an automatic line. The strap diverter 322 is actuated in the automatic feed sequence only to feed strap into the machine. The curved block 326 encourages the strap 102 to bend upward during the feeding sequence. Once the strap has been established in the machine, the strap supply is maintained by the strap loop in the accumulator 300.

Feed and Tension Unit:

Figure 9 is a first isometric view of the feed and tension unit 400 in accordance with an embodiment of the invention. The feed and tension unit 400 is driven by the main drive assembly 600, which is discussed in detail below. Figure 10 depicts the path of the strap 102 as it moves through the various components of the feed and tension assembly 400. As best seen in Figure 10, there are three sets of wheels in the feed and tension unit 400: A first set of wheels is comprised of a primary tension drive wheel 402 and a primary tension pinch wheel 404. The primary tension wheels, 402 and 404, provide the majority of strap take-up during the start of tension cycle and during the initial stages of a bundling operation. A second set of wheels is comprised of a secondary tension drive

wheel 408 and a secondary tension pinch wheel 406. As described in more detail below, the primary and secondary tensioning components provide a two-stage force operation for enhanced controllability of the strap 102 during bundling and sealing operations, such as allowing the strap 102 to be quickly accelerated around the bundle. Another set of drive wheels is a feed drive wheel 410 and a feed pinch wheel 412. The feed wheels, 410 and 412, control and direct the strap 102 during the feeding operation.

Unlike some prior art strapping machines which feed the strap around several bends in the feed and tension unit prior to reaching the track, the feed and tension unit 400 features a simplified strap path allowing the strap 102 to be fed in a straighter path than previously achievable. As best shown in Figure 10, the associated drive and pinch wheels discussed above are positioned in an approximately triangular orientation causing the strap 102 to follow an approximate "V-shaped" path where the included angle of the "V" is in the range of about 20 to 40 degrees from the horizontal. The size of the feed drive wheel 410 may be configured to gently guide the strap 102 around the feed drive wheel 410, especially when a fairly rigid strap material is used for high-force bundling operations.

Still referring to Figure 10, the feeding direction of the strap is indicated as "F" and the tensioning direction is indicated as "T." This configuration results in greater strap tension due to the increased contact area on the feed drive wheel 410. In addition, less bending of the strap reduces friction throughout the system, increasing the reliability of strap feeding. Less bending also reduces the tendency of the strap to permanently deform and cause feeding difficulties. Thus, the feed and tension unit 400 of the present invention advantageously reduces or eliminates kinks in the strap which lead to feeding difficulties. While some strapping machines of the prior art typically turned the strap through a total of 360 degrees or more prior to reaching the track, the feed and tension unit 400 greatly reduces the amount of turning of the strap. For example, in the embodiment shown and described in the foregoing figures, the direction of the strap 102 is limited to a change in direction of between approximately 180 and 220 degrees as the strap 102 is received from the dispenser, manipulated around the V-shaped path shown in Figure 10, and then directed to the track assembly 700.

Referring back to Figure 9, as the strap 102 passes through each of the above described pinch wheels, a plurality of inner guides 420 and a plurality of outer guides 422 keep the strap 102 in line as it is directed toward the track assembly 700.

Figure 11 is an enlarged partially-exploded isometric view of a pair of inner and outer strap guides 420 and 422 of the feed and tension unit 400 of Figure 8. As best viewed in Figure 12, each "L-shaped" inner guide 420 has a roughly L-shaped cross-section and is coupled to a matching "L-shaped" outer guide 422 to form a strap channel 424 through which the strap 102 passes.

Referring back to Figure 11, the inner and outer guides 420 and 422 are secured in position on a plurality of guide pins 426 which project from a back plate 430 (Figure 9) of the feed and tension unit 400 by a plurality of retaining knobs 428, although a variety of other securing devices may be used. In Figure 9, note that the upper outer guide 422 adjacent to the primary tension pinch wheel 404 is not shown in order to better illustrate the path of the strap 102 as the strap is directed toward the primary tension drive and pinch wheels, 402 and 404 and to provide a perspective view of one of the "L-shaped" inner guides 420. The feed and tension unit 400 also includes a number of solenoids 470 for engaging and disengaging the primary pinch wheel 402 and the feed pinch wheel 406. The operation of the feed and tension unit along with the solenoids 470 is described in detail below.

Sealing Head Assembly:

Figures 13 through 17 illustrate one embodiment of a sealing head assembly 500 for sealing the strap 102 during a bundling operation. Figure 13 is an isometric view of the sealing head assembly 500 of the strapping machine 100 of Figure 2. Figures 14 and 15 are top elevational and back elevational views, respectively, of the sealing head assembly 500 of Figure 13. The sealing head assembly 500 is comprised of a motor-driven main shaft 518 and a series of cams 502 which mechanically sequence the gripping, sealing and cutting functions. These cams 502 drive three sliding members 522, three rotating arms, a heater arm 532, anvil follower arms 534, and an inner slide follower arm 536 (Figure 15).

A cam roller is connected to each rotating arm. The cams permit both linear and pivoting follower arrangements. The left-hand gripper 504, the right hand gripper 508, and the platen 512 are linear followers meaning that their cam rollers operate directly over the sealing head cam centerline. The heater arm 532, the anvil follower arm 534, and the inner slide follower arm 536 pivot about an arm pivot shaft 538 proximately located and substantially parallel to the motor driven main shaft 518. This configuration causes the rotating arms to pivot through an arc as the arm mounted cam rollers follow their respective cam profiles. The inner slide follower arm 536 is not solidly connected to the inner slide 520 as it is on the heater blade 510 and the anvil 506. This arrangement permits the inner slide 520 to slide linearly inside the anvil rather than pivoting through an arc. The inner slide follower arm 536 is connected to the inner slide 520 by a pin and slot arrangement converting the pivoting movement of the inner slide follower arm 536 to linear motion required for the inner slide 520.

One slide member 522 is coupled to the right-hand gripper 508, another slide member 522 is coupled to the left-hand gripper 504, and the third slide member 522 is coupled to the press platen 512. The sliding members 522 perform the gripping, sealing and cutting functions, while the pivoting arms 524 move the inner slide 520, the anvil 506, and the heater blade 510 into and out of a strap path as required during a bundling operation.

Figure 16 is an exploded isometric view of the press platen 512 and cutter 514 of Figure 17. As shown in Figure 16, the press platen 512 includes a pair of mounting nubs 511, and the cutter 514 includes mounting recesses 513. A spring 515 is disposed between the cutter 514 and the press platen 512 with one end of the spring 515 being partially disposed within a seating hole 517 located in the press platen 512. The cutter 514 has cutting edges 519 at both ends, allowing the cutter 514 to be reversibly positioned on the press platen 512 for added operational life. In the embodiment shown in Figure 16, the cutting edges 519 are slanted at an angle α. Although a wide variety of cutting edge angles α may be used, a cutting edge angle in the range of approximately 5 to 15 degrees is desirable, while a cutting edge angle of about 9 degrees is preferred.

During assembly, the spring 515 is compressed between the cutter 514 and the press platen 512 until the two mounting recesses 513 slideably engage two of the mounting nubs 511. Recall that the cutter 514 has a pair of mounting recesses 513 situated near each end of the cutter 514; this allows the cutter 514 to be reversibly mounted onto the press platen 512. The cutter 514 and the press platen 512 are then positioned securely between the left and right-hand grippers 504 and 508 such that the pressure from these components maintains the compression of the spring 515. The cutter 514 and press platen 512 can then be engaged with the third slide member 522. This arrangement provides the necessary scissors action to sever the strap 102.

An advantage sealing head assembly 500 illustrated in Figures 13 through 17 is that the cutter 514 is removably and replaceably mounted to the press platen 512 by slideably engaging onto the press platen 512. This configuration allows the cutter 514 to be more easily removed for replacement or maintenance than in existing strapping machines. In addition, the dual blade and reversible positioning of the cutter 514 essentially doubles the useful life of the cutter.

Main Drive Assembly:

Figure 18 illustrates one embodiment of a main drive assembly 600 for driving various components, in particular sprockets, drive belts, and shafts used to power the feed and tension assembly 400 and the sealing head assembly 500. The main drive assembly 600 includes a sealing head drive motor 602 coupled to a jackshaft 604. The jackshaft 604 is supported by a pillow block bearing 606.

An opposite end of the jackshaft 604 is rotatably coupled to a first pulley 608. The first pulley 608 can be toothed to accept toothed-belts. The use of toothed belts allows for a more smooth and consistent transmission of power. As illustrated in Figure 18, the first pulley 608 may be engaged with more than one belt, for example the sealing head pulley 608 may be configured with a sufficient width for accepting both a sealing head drive belt 610 and a drive wheel belt 612. The sealing head drive belt 610 transmits power

for the operation of the sealing head assembly 500 while the drive wheel belt 612 transmits power for the feed and tension unit 400.

The sealing head drive belt 610 is directly coupled to a sealing head pulley 614, which in turn, is rotatably coupled directly to a spring clutch 616. The drive wheel belt 612 is configured to make an approximate 90-degree turn as it engages a pair of intermediate pulleys 618. The drive wheel belt 612 continues on from the intermediate pulleys 618 to engage a drive wheel clutch 620. The sealing head drive motor 602, the spring clutch 616, and the drive wheel clutch 620 can each be operatively coupled to a control system 700, for example, by electrically conductive leads.

In the present embodiment, the spring clutch 616 is a wrap spring clutch and the drive wheel clutch 620 is an electromagnetic clutch. Additionally and alternatively, other spring clutch embodiments may be used. An advantage of the wrap-type spring clutch 616 is that it can stop the sealing head cams 502 at the proper degree of rotation during each stage of the operational cycle in a reliable and predictable manner. Equivalently, the spring clutch 616 can stop the cams 502 in their home position at the end of each cycle. An advantage of the electromagnetic-type drive wheel clutch 620 is that the clutch 620 can be set to slip at a predetermined torque level. The torque level, in turn, can be calibrated to a voltage that is supplied to a coil located within the electromagnetic drive wheel clutch 620. The slip in the drive wheel clutch 620 determines the amount of secondary tension that is applied to the strap 102.

Another advantage of the main drive assembly 600 is that the drive wheel belt 612 travels through an approximately 90-degree angle. This arrangement, commonly referred to as a "mule drive," eliminates a 90-degree gearbox commonly found in the drive systems of existing strapping machines. Thus, this configuration can reduce the complexity of the system and cost of fabrication. As a result, the drive system's reliability and maintainability are also improved.

Figure 19 illustrates another embodiment of the main drive assembly 600 that includes a sealing head drive motor 602 powering a sealing head drive belt 610. The sealing head drive belt 632 is directly coupled to a spring clutch 616 through a pulley 608.

As in the previous embodiment, it is preferable if the belts are "toothed." In addition, a secondary tension drive motor 622 can be coupled to the drive wheel clutch 620 through a secondary tension belt 624.

Track Assembly:

Figure 20 is an isometric view of a track 700 in accordance with an embodiment of the invention. Figure 21 is a partial sectional view of a straight section 702 of the track 700 of Figure 20 taken along line 21-21. Figure 22 is an isometric view of a corner section 704 of the track 700 of Figure 20. Figure 23 is a partially exploded isometric view of a straight section 702 of the track 700 of Figure 20. In brief, the track 700 directs the strap 102 around the strapping station 120 (Figure 2). During a bundling operation, the strap 102 exits from the sealing head assembly 500 and is then guided completely around the track 700, eventually doubling back on itself in the region of the sealing head assembly 500.

The track 700 includes a plurality of straight sections 702 and a plurality of corner sections 704. As shown in Figures 20 and 21, each straight section 704 includes a guide support 706 at each end of the straight section 704. A straight slotted cover 708 and a straight backplate 710 are coupled to the straight supports 706 to form a portion of a guide passage 716 that retains the strap 102 as the strap is guided through the track 700. Each straight slotted cover 708 includes a straight inner surface 722 on the inner circumference of the guide passage 716, and a straight outer surface 724 on the outer circumference of the guide passage 716. Referring to Figure 21, the straight sections 706 and the corner sections 704 are keyed to fit on a raised "T" section 714 of an outer arch 712. The outer arch 712 forms a frame for the other components of the track 700.

As shown in Figure 22, each corner section 704 includes a corner slotted cover 730 and a corner backplate 734 coupled to a plurality of guide supports 706. The corner slotted cover 730 and corner backplate 734 form a portion of the guide passage 716 therebetween. Each corner slotted cover 730 includes a corner inner surface 736 on the inner circumference of the guide passage 716, and a corner outer surface 738 on the outer

circumference of the guide passage 716. In this embodiment, the corner slotted cover 730 and the corner backplate 734 are coupled to the guide supports 706 using a four-bar linkage assembly 740 that permits the corner slotted cover 730 to pivotably open to release the strap 102 from the guide passage 716. Figure 22 illustrates one of the inner bars 742 of the four-bar linkage assembly 740. An enlarged opening 744 permits the corner slotted cover 730 to pivotably open about an axis of rotation that is oriented approximately 45 degrees from the horizontal.

As best shown in Figure 23, the straight slotted cover 708 and the straight backplate 710 are spring-loaded by a plurality of springs 732. The straight slotted covers 708 and the straight backplates 710 are hinged on pivot pins 746 that are approximately parallel to the path of the strap 102 in the guide passage 716. The pivot pins 746 are inserted through corresponding apertures 748 and 750 in the straight slotted cover 708 and straight backplate 710, respectively, and rotate about an axis defined by the longitudinal axis of the pivot pins 746. The pivot pins 746 are retained in position by snap-on retainers or any other convenient retainer element.

The springs 732 are inserted through a corresponding aperture 752 in the straight backplate 710 and are coupled to the straight slotted cover 708 by a spring retaining pin 754. In one embodiment, the spring retaining pins 754 are identical to the pivot pins 746 and are retained within corresponding apertures 756 in the straight slotted cover 708 by the snap-on retainers. The springs 732 are thus coupled on a proximal end to the straight slotted cover 708 by the spring retaining pins 754 and are retained within the aperture 752 by an enlarged distal end, sometimes referred to as a circle cotter. This arrangement allows the straight slotted cover 708 to pivot open and release the strap 102 and subsequently and automatically close due to the spring force exerted on the straight slotted cover by the springs 732. One skilled in the art will appreciate that various sizes of straight slotted covers 708 may be used depending on the size and shape of the strap 102. In the illustrated embodiment, the guide passage 716 is sized to receive strap sizes of approximately 19 mm.

One advantage of the track 700 of the present invention is the modular construction of the straight and corner sections, 702 and 704, which allows the track 700 to

be incrementally extended in length and height. Because the straight and corner sections 702 and 704 are keyed to fit a raised section 714 of an outer arch 712 (Figure 21), these components form an easily assembled slide-together arch system, enabling the size of the track 700 to be easily modified for various combinations of length and height. Thus, the size of the strapping station 120 (Figure 2) may be quickly and efficiently modified for a variety of bundle sizes.

Another advantage of the track 700 is that by pivoting the straight slotted covers 708 parallel to the strap path, and by pivoting the corner slotted covers 730 on the four-bar linkage assemblies 740, the strap 102 itself also provides an opening force during tensioning to assist the solenoids 726 (Figure 24) in opening the track. During the tension cycle, the strap 102 is drawn against the straight inner surfaces 722 and the corner inner surfaces 736, forcing the straight slotted covers 708 and corner slotted covers 730 to pivotably open in the manner described above. Thus, the track 700 does not require complex hydraulic or pneumatic actuation systems to open the track sections and release the strap during tensioning. This arrangement reduces the cost of the track sections, simplifies maintenance of the track, and reduces the likelihood of the strap 102 being jammed or snagged during the strap release process.

A further advantage of the track 700 is that the forces exerted by the strap 102 on the straight slotted covers 708 and corner slotted covers 730 during the strap feed cycle actually assist in keeping the track closed during the strap feed process. The configuration of the track as described above allows the strap 102 to push outwardly on the straight outer surfaces 724 and the corner outer surfaces 738 to create a moment (*i.e.*, a force vector) that forces the straight slotted covers 708 and the corner slotted covers 730 toward the closed position. This aspect of the invention reduces misfeeds of the strap, and eliminates the need for complex hydraulic or pneumatic actuation systems to close the track and keep it closed during the strap feed cycle.

Control System:

The strapping machine 100 is controlled by a control system 800, illustrated in Figure 25 that may include a programmable logic controller (PLC) 802, which operates in conjunction with various input and output devices and controls the major subassemblies of the strapping machine 100. Input devices may include, for example, momentary and maintained push buttons, selector switches, toggle switches, limit switches and inductive proximity sensors. Output devices may include, for example, solid state and general purpose relays, solenoids, and indicator lights. Input devices are scanned by the controller 802, and their on/off states are updated in a controller program. The controller 802 executes the controller program and updates the status of the output devices accordingly. Other control functions of the controller 802 are described below in further detail.

In one embodiment, the programmable controller 802 and its associated input and output devices may be powered using a 24 VDC power supply. The controller 802, power supply, relays, and fuses may be contained within a control panel, as illustrated in Figure 25. The momentary and maintained push buttons, selector switches, and toggle switches may be located on a control pendant or a control panel cover. The limit switches, inductive proximity sensors, and solenoids are typically located within the strapping machine 100 at their point of use. At least one indicator light may be mounted on the top of the track 700 and may light steadily to indicate an out-of-strap condition, and may flash to indicate a strap mis-feed condition, for example.

One commercially-available PLC 802 suitable for use with the strapping machine 100 is the T100MD1616+ PLC manufactured by Triangle Research International Pte Ltd in Singapore. This device includes sixteen NPN-type digital outputs, four of which are NPN Darlington Power Transistor types and twelve of which are N-channel power MOSFET types. Two of the outputs are capable of generating a Pulse Width Modulated (PWM) signal with a frequency and duty cycle determined in the programming software. Also included are four input channels of 10-bit analog-to-digital converters. Two of the input channels are buffered by operational amplifiers with a x5 gain accepting analog signals of 0-1V full scale. The remaining two channels are unbuffered and accept 0-5V full

scale analog signals. The unit includes a stable 5V (+/- 1% accuracy) regulated DC power supply to be used as a voltage reference for the analog inputs. A single channel 8-bit digital-to-analog output utilizing a 0-20mA current loop signal, also resides on the PLC. One skilled in the art will understand that an industry standard PLC may also be used in place of the PLC described above.

The T100MD1616+ PLC has communication ports, including an RS232C port for program uploads, downloads and monitoring, a two-wire RS485 network port, a 14-pin LCD display port for possible future use as a diagnostic display driver, and a port for expansion. The PLC itself is controlled by a custom CPU that has both EEPROM and RAM memory backup. The controller program used to program the controller 802 may, for example, include Trilogi programming software available from Triangle Research International Pte Ltd, and may include both ladder logic and Tbasic type code (described more fully at www.tri.com.sg/index.htm).

Strapping Machine Operation:

In brief, the operation of the strapping machine 100 involves paying off strap 102 from a strap coil 214 located on the dispenser 200 (Figure 3) and feeding a free end of the strap 102 through the accumulator 300, through the feed and tension unit 400, up through the sealing head assembly 500, and then around the track 700. After the strap 102 is fed around the track 700, the free end is guided back into the sealing head assembly 500. At this point, the strap 102 is in position to start a strapping cycle where the strap 102 can be tensioned and secured about a bundle of objects.

The strapping machine 100 can be operated in either a manual strapping mode or an automatic strapping mode. The strapping machine 100 typically operates in an automatic production line in the automatic strapping mode. If the operator has to intervene or the machine 100 needs to be repaired off line, the machine can be operated in the manual strapping mode. The manual mode can be used to apply single or multiple straps about a bundle of objects while an operator actuates a switch. Likewise, the automatic mode is primarily used to apply a single strap to a bundle of objects when a switch, for example an

optical proximity switch, senses a moving bundle within the strapping station 120. The automatic mode can be used in conveyor lines and in conjunction with other automated machinery. The strapping machine can also be programmed to apply multiple straps to a bundle of objects when in automatic mode.

<u>Strap Feeding Operation:</u>

Before a feeding operation can be commenced, the accumulator 300 needs to be filled. Filling the accumulator 300 first substantially reduces the need to quickly accelerate the coil during the feeding the feeding sequence. To initially feed strap 102 into the strapping machine 100, a free end of strap is removed from the strap coil 214 and guided into the accumulator 300. The presence of the strap 102 causes the strap exhaust switch 222 to be toggled, thus sending a signal to the controller 802 that a continuous line of strap 102 exists between the dispenser 200 and the accumulator 300. The strap 102 is guided between the accumulator drive wheel 312 and the accumulator pinch wheel 314, triggering the accumulator feed switch 316. The accumulator drive and pinch wheels, respectively, are then employed to pull strap into the accumulator with the strap eventually being guided through the feed and tension unit 400 and around the track 700.

As the accumulator chamber 306 fills with strap 102, an optical or proximity sensor, for example a lower limit photoeye (not shown), can monitor loop in the accumulator chamber and transmit a signal to the controller 802 when the loop is at capacity or when the loop contains a predetermined amount of strap thereon. In response to the signal from the accumulator, the controller 802 de-energizes the accumulator motor 310 and activates the dispenser brake 210 to halt the accumulator filling sequence. A time delay occurs between when the dispenser brake 210 is activated and when the accumulator motor 310 is de-energized in order for a substantial portion of slack to be taken from the dispenser strap coil 214. This time delay keeps the strap 102 adequately taut between the dispenser 200 and the accumulator 300 so that any exposed strap does not become twisted or kinked.

In continuing to follow the free end of the strap 102 through the initial feeding process, the strap free end is guided from the accumulator 300 into the lower chamber 424 formed by the lower "L-shaped" guides, 420 and 422, respectively, of the feed and tension unit 400. The first set of wheels to pinch the strap 102 is the feed drive wheel 408 and the feed pinch wheel 406. Figure 26 illustrates one embodiment where the pinch force applied by the feed drive and feed pinch wheels can be regulated by a pulse width modulated solenoid 470a in two stages. In the first stage, a full feed force is applied while in the second stage a reduced feed force is applied. Altering the pulse width modulation of the feed pinch solenoid 470a can control the amount of pinch force. Because the pinch force exerted by a solenoid 470a on the strap 102 varies with supplied voltage, supplying a pulse width modulated voltage signal to the solenoid 470a provides the ability to vary the force exerted by the solenoid 470a. As the force exerted by the solenoid 470a is decreased, the strap 102 is permitted to slip on the feed drive wheel 408 more easily, thus resulting in a decreased amount of pull on the strap 102. Commercially available solenoids suitable for this purpose include those solenoids available from Ledex® Actuation Products of Vandalia, Ohio.

The frequency of the pulses input to the solenoid affects the operation and performance of the solenoid. Generally, as the frequency of the pulses is increased, the adjustability of the pinch force exerted by the solenoid is improved. A higher frequency of pulses results in better controllability of the pinch force and an improved reaction time for the feed pinch wheel 406. For example, using the above-referenced solenoids available from Ledex® Actuation Products, a pulse frequency of 8000 Hz has been successfully used.

The feed drive and pinch wheels, 408 and 406, feed the strap through the sealing head assembly 500, around the track 700, and back into the sealing head assembly 500. When the free end of the strap 102 has been guided around the track and reaches the sealing head assembly 500, the arrival of the free strap end is detected by a feed stop switch (not shown) located with the sealing head assembly 500, which transmits a feed stop signal to the controller 802. The controller 802 then sends a feed pinch signal to the feed pinch

wheel 406 to disengage the feed pinch wheel 406 from the strap 102, and the feeding sequence is complete.

Tensioning/Bundling Operation:

During a tensioning or bundling operation, the tensioning of the strap occurs in two stages, a primary tension stage and a secondary tension stage. In the primary tensioning stage, the strap 102 is pinched between the primary tension drive wheel 402 and the primary tension pinch wheel 404. Referring back to Figure 26, the primary tension solenoid 470b engages the primary tension pinch wheel 404 against the primary tension drive wheel 402 with full pinch force to ensure that the strap 102 is sufficiently engaged and can be pulled free of the track guide passage 716. As the strap 102 is pulled tightly around the bundle during the primary tensioning sequence, the primary tension pinch wheel 404 stops rotating due to the slippage of the strap. The slippage of the strap 102 coincides with the secondary tensioning stage, which is discussed in more detail below, where the pinch force supplied by the primary tension pinch wheel 404 and the primary tension drive wheel 402 is reduced by altering the pulse width modulation of the primary tension solenoid 470b.

Using pulse width modulation to control the pinch forces exerted by the solenoids 470a and 470b during feeding and primary tensioning of the strap advantageously allows the operator a larger range of adjustment than is possible with a hydraulically operated strapping machines currently available. The two-stage force operation provides improved controllability of the strap 102 movements.

The feed and tension unit 400 can include a proximity sensor located adjacent to the primary tension pinch wheel 404. The proximity sensor is operatively coupled to the controller 802. The proximity sensor monitors the primary tension pinch wheel 404 during primary tensioning, such as by monitoring the passing of notches in the wheel 404 in order to detect the stall of the primary tension pinch wheel 404. The proximity sensor transmits signals to the controller 802. If the signals from the proximity sensor indicate that the primary tension pinch wheel 404 is not turning due to the slippage

of the strap 102 on the primary tension drive wheel 402, then the controller 802 initiates the secondary tensioning sequence.

The secondary tensioning sequence involves the strap being pinched between the secondary tension pinch wheel 412 and the secondary tension drive wheel 410. Referring to Figure 26, a secondary tension pinch solenoid 470c may be used to control the amount of tension in the strap. Then, the secondary tension drive wheel 410 is driven by the drive wheel clutch 620, located in the main drive assembly 600, until the drive wheel clutch 620 starts to slip. The secondary tensioning operation allows the strap 102 to be bound tightly around the bundle of objects located in the strapping station 120. After the strap 102 is tensioned to the point that the drive wheel clutch 620 slips, the controller 802 permits a predetermined amount of time to pass to allow the strap to be cut and sealed. Once the sealing operation is complete, the feeding sequence may then be repeated.

One advantage of the strapping machine 100 is that the various pinch wheels are actuated by the solenoids. Using a two-stage pulse width modulated (PWM) signal, the solenoids are adjustably controllable by the user during strapping machine 100 operation. During the first stage, the solenoid is given a PWM signal at a constant duty cycle. For the second stage, the solenoid is controlled using a PWM signal with a duty cycle that is user-adjustable via, for example, a potentiometer. Since the average voltage seen by the solenoid is determined by the duty cycle, varying the duty cycle will vary the amount of force the solenoid pulls. Thus, the pinch wheels may be adjustably controlled during operation of the strapping machine 100.

The tensioning sequence discussed above provides enough force on the strap 102 to pull the strap 102 from the track guide 716. The track 700 is configured to permit the strap 102 to smoothly and uniformly be removed from the track guide 716. As the strap 102 is tensioned around the bundle of objects, the straight and corner slotted covers can be opened, allowing the strap 102 to pull clear of the guide passage 716. This stripping action can be further assisted by the track opening solenoids 726 with actuating links 728 acting on the left hand and right hand lower corners of the track as illustrated in Figure 24. Because the respective track sections are mechanically linked together by connecting pins,

this allows the solenoids to open the entire track from the bottom. Figure 21 illustrates the open position of the slotted cover 708 in phantom to assist in a more complete understanding of the invention.

After the strap 102 clears the guide passage 716 and the strap is pulled down around a bundle of objects, the solenoids 726 are released, thus causing both the straight and corner slotted covers, 708 and 730, respectively, to be closed by the springs 732. At this point, the track 700 is ready for the strap 102 to be fed again after the bundling operation has been completed. The V-shape of the guide passage 716 in the corner section 704 helps assure that the strap removal begins in the corner sections 704 rather than in the straight sections 702 of the track 700. When the strap 102 is removed from the track 700, the V-shape of the guide passage 716 in the corner section 704 causes the track cover 730 to begin opening in the corner section 704 first.

Strap Sealing Operation:

Once the strap 102 has been sufficiently tensioned around the bundle of objects, the non-free end of the strap can be cut and then both ends of the strap 102 can be sealed together. The sealing operation commences when several sealing head cams 502 in the sealing head assembly 500 begin to rotate, forcing the left-hand gripper 504 to pinch the free end of the strap 102 against the anvil 506. Those skilled in the art will recognize that the strapping machine 100 can be configured to accommodate a right-hand gripper instead of the left-hand gripper 504. After gripping the strap 102 in the sealing head assembly 500, the feed and tension unit 400 retracts the excess strap 102 from the track 700 (*i.e.*, the tensioning operation discussed above).

The cams 502 can operate as cycloidal cams allowing the sealing head assembly 500 to operate smoothly at increased speeds. The term "cycloidal cam" means a cam with cycloidal displacement generated by taking a sinusoidal acceleration function that has a magnitude of zero at its beginning and end, and integrating the function to obtain the velocity and displacement of the cam follower. In addition, the cam follower pressure angles can be minimized to extend the life of the cams.

With the free end of the strap 102 being gripped by the left-hand gripper 504 and the non-free end of the strap 102 being gripped by the right-hand gripper 508, the tension applied by the various pinch wheels on the strap can be released. A cutter 514 is then maneuvered toward the non-free end of the strap 102 to cut the strap, thus creating a second free end of the strap 102. Both free ends of the strap 102, which remains securely taut around the bundle of objects, are configured in an overlapping position.

In one embodiment, the strap 102 used to bundle objects can have a heat-activated adhesive applied thereon. Preferably, the adhesive on the strap 102 is applied to the strap 102 during the manufacturing process of the strap. Heat is applied to the strap by inserting the heater blade 510 between the two overlapping ends of the strap and lightly pressing the ends against the blade 510 by raising the press platen 512. The press platen 512 is then lowered slightly to allow the heater blade 510 to be removed from between the strap ends. Next, the press platen 512 is raised again to press both ends of the strap against the anvil 506 for bonding and cooling the adhesive. As the sealing head cams 502 continue to rotate, the press platen 512 lowers slightly once more allowing the anvil 506 to open and release the now sealed strap ends. After the strap is released, the anvil 506 is closed and the strapping cycle is completed.

The following discussion of the operation of the main drive assembly 600 will assist those skilled in the art to better understand the cam sequence discussed above and also provide more detail on the sealing operation. In short, the main drive assembly 600 controls the rotation of the cams 502, which in turn control the movements of the anvil 506, heater blade 510, and press platen 512, among others. As seen in Figure 18, the sealing head drive motor 602 drives the sealing head assembly components 500 by means of the sealing head drive belt 608 and the spring clutch 616. Now referring back to Figure 13, the rotation of the sealing head assembly main shaft 518 causes the keyed cams 502 to rotate and perform the necessary gripping, sealing and cutting functions. During a first period of rotation, the main shaft 518 rotates to the first of three stops on the spring clutch 616, causing a cutter-gripper assembly 526 to grip the strap 102 and the inner slide 520 to move out of the strap path. The sealing head drive motor 602, through the secondary

tension clutch, then tensions the strap about the bundle, as previously discussed. When the strap tensioning is complete, the controller 802 pulses the spring clutch 616 allowing the cams 502 to rotate into a second period of rotation.

During the second period of rotation, which commences the dry sealing process, either the left-hand gripper or right-hand gripper 504 grips the strap just ahead of the feed stop switch 516. Once the strap is firmly gripped, the tension in the strap, upstream of the track assembly 700, is released. This signals the press platen 512 and the cutter 514 rise to cut the strap 102 and press the strap against the heater blade 510. The cams 502 continue to rotate through a dwell section as the adhesive on the strap melts on the heater blade 510. After a predetermined time for melting has passed, the press platen 512 and the cutter 514 retract slightly allowing the heater blade 510 to retract. The accurate and sequential timing of the dry sealing operation is important in achieving a sufficient amount of heat to properly secure the straps without imparting too much heat and causing the strap bond to be weakened. The dry sealing operation, accurately timed through the use of keyed cams, has the advantage of not using water on the water soluble straps, such that the amount of heat applied can be accurately controlled to repeatedly produce strong, reliable bundled objects.

After the heater blade 510 retracts, the press platen 512 rises again to press the melted adhesive on the two strap ends together for cooling and sealing. The sealing head main shaft 518 continues to rotate during a third period of rotation until a clutch trigger (not shown) disengages the spring clutch 616. The sealing head assembly 500 remains in this position for a predetermined time until the controller 802 again energizes a spring clutch solenoid (not shown) located within the spring clutch 616. The continued rotation of the cams 502 release the press platen 512 and allows the left and right-hand grippers, 504 and 508, to travel back to their home positions. One of the cams 502 then pivots the anvil 506 out of the strap line past a pair of strippers 530. As the anvil 506 pivots, the strippers 530 push the strap off of the anvil 506. After the strap 102 is out of the sealing head assembly 500, the anvil 506 closes, and the cams 502 reach their home positions. With the cams 502 at their home positions, the spring clutch 616 reaches the

third and final stop as the home position switch 516 (Figure 13) signals the controller 802 to begin another feed sequence.

The detailed descriptions of the above embodiments are not exhaustive descriptions of all embodiments contemplated by the inventors to be within the scope of the invention. Indeed, persons skilled in the art will recognize that certain elements of the above-described embodiments may variously be combined or eliminated to create further embodiments, and such further embodiments fall within the scope and teachings of the invention. It will also be apparent to those of ordinary skill in the art that the above-described embodiments may be combined in whole or in part with prior art methods to create additional embodiments within the scope and teachings of the invention.

Strap Replacement Operation:

When the strap coil 214 is depleted, the strap exhaust switch 222 is no longer actuated which stops the strapping machine 100 until the strap coil 214 is replenished. A braking circuit is used to prevent the accumulator motor 310 from drawing the free end of the strap 102 into the accumulator 300. The remaining loose tail of strap can then be pulled out of the accumulator 300 before a new strap coil 214 is installed. The empty strap coil 214 can be replaced by removing the outer hub 208 and then removing the strap coil 214. Next, a fresh strap coil 214 can be installed with the strap 102 wound in a clockwise direction. Finally, a nut securing the outer hub 208 can be securely re-tightened.

Thus, although specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. The teachings provided herein of the invention can be applied to other methods and apparatus for strapping bundles of objects, and not just to the methods and apparatus for strapping bundles of objects described above and shown in the figures. In general, in the following claims, the terms used should not be construed to limit the invention to the specific embodiments disclosed in the specification. Accordingly, the invention is not limited by the foregoing disclosure, but instead its scope is to be determined by the following claims.